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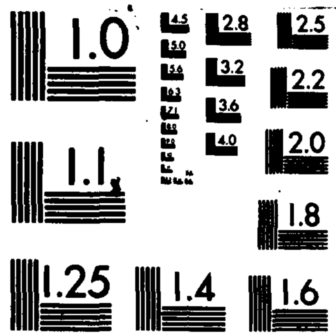

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Final Scientific Report

of

A Study of Low Energy Electron Precipitations
and Auroral Phenomena by Using the USAF Polar Orbiting Satellites

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Air Force Office of Scientific Research Grant
AFOSR-79-0010
(October 1, 1978 to September 30, 1983)
to
Applied Physics Laboratory
The Johns Hopkins University

Principal Investigator
Dr. Ching -I. Meng

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The main objective of this research project is to study the low energy electron precipitation and auroral phenomena over polar regions. The research is based on using various types of measurements from several USAF satellites at both low altitude polar orbits and high altitude geosynchronous orbits. They are focused on (1) to investigate the different kinds of polar electron precipitations as various auroral displays, the polar cusp region, conjugate photoelectrons, polar rain

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over the polar cap, (2) to determine precipitation characteristics for various kinds of magnetospheric and geophysical phenomena, (3) to investigate the physics and configuration of the polar cusp region and the polar cap region, and (4) to understand the morphology of magnetospheric particle population. The results of these studies can lead us to a better understanding of the interaction between the solar-wind and the geomagnetic field and also the coupling between the magnetosphere and the ionosphere. Numberous research results were obtained and have been published in 34 scientific papers (or are in press and submitted) in leading international scientific journals and monographs. This report consists of two parts. In the first part, these scientific articles are grouped under five major categories, namely (1) Auroral display morphology and (2) Source of auroral electrons, (3) Polar cap dynamics and magnetospheric configuration dynamics, (4) Polar cusp morphology, and (5) Magnetospheric morphology and miscellaneous. Some of the papers dealing with more than one of these topics are listed in relevant groups. The summary of each publication is given in the second part of this report.

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I. INTRODUCTION

The main objective of this research project is to study the low energy electron precipitation and auroral phenomena over polar regions. The research ~~are~~ is based on using various types of measurements from several USAF satellites at both low altitude polar orbits and high altitude geosynchronous orbits. ~~They~~ These are focused on: (1) to investigate the different kinds of polar electron precipitations such as various auroral displays, the polar cusp region, conjugate photoelectrons, polar rain over the polar cap; (2) to determine precipitation characteristics for various kinds of magnetospheric and geophysical phenomena; (3) to investigate the physics and configuration of the polar cusp region and the polar cap region; and (4) to understand the morphology of magnetospheric particle population. The results of these studies can lead us to a better understanding of the interaction between the solar-wind and the geomagnetic field and also the coupling between the magnetosphere and the ionosphere.

The Air Force Office of Scientific Research Grant AFOSR-79-0010 to The Johns Hopkins University, Applied Physics Laboratory has supported the aforementioned investigations since October 1978. Numerous research results were obtained and have been published in 34 scientific papers (or are in press and submitted) in leading international scientific journals and monographs. The following is the list of these scientific articles which are grouped under five major categories, namely (1) Auroral display morphology, (2) Source of auroral electrons, (3) Polar cap dynamics and magnetospheric configuration dynamics, (4) Polar cusp morphology, and (5) Magnetospheric morphology and Miscellaneous. Some of the papers dealing with more than one of these topics are listed in relevant groups.

II. AURORAL DISPLAY MORPHOLOGY

The relationship between the polar aurora and the precipitation of charged particles was first suggested by Dalton and Gauss in mid-19th century; they regarded the polar aurora as an electrical phenomenon. Modern auroral science was pioneered by Birkeland in 1896 and by Stormer. They suggested that auroras are caused by beams of electrons ejected from the Sun and guided into the polar atmosphere by the geomagnetic field lines; note that the discovery of electrons by J. J. Thomson was made in 1897. However, evidence of the production of auroras by incoming charged particles along the geomagnetic field lines was not found until the early fifties of this century. Ground-based photometric observations of the auroral spectrum revealed (1) the Doppler broadening of the Hα line at λ6562.8 measured in the direction of the magnetic horizon, (2) the Doppler shift towards the violet side, and (3) asymmetric broadening viewed along the magnetic zenith. These optical phenomena are associated with hydrogen atoms which emit the Balmer lines as they descend along the field lines.

The first direct measurement providing information on charged particle precipitation over auroral zone latitudes was made incidentally during a latitudinal survey of primary cosmic rays by using Geiger tubes and scintillation counters aboard rockoons, small rockets carried aloft by balloons and ignited in the stratosphere. It was found that the radiation consisted of X-rays in the 10-100 keV range appeared frequently above the atmosphere in a geomagnetic latitudinal range, from 65° to 75°, corresponding to the visual auroral zone. These X-rays, were assumed to be associated with radiations of primary auroral electrons. The X-ray radiation was also detected at altitudes as low as 30 km by balloon experiments. Since then, particle precipitations

at high altitudes have been studied by a variety of techniques. Extensive information has been derived from direct measurements of electrons with detectors onboard rockets and satellites and indirect observations of the X-ray bremsstrahlung from balloons as well as from ground-based photometric measurements of light emissions produced by precipitated electrons.

The continuous auroral imagery and electron precipitation measurement from USAF DMSP satellites provide the most extensive data basis for investigating auroral morphology. Furthermore, simultaneous observations of auroral displays and the precipitation from DMSP are unique in space physics and they are essential in understanding the physics of auroras. There are 16 papers published (or in press) in scientific journals from our investigation on this topic. A major effort was to understand the auroral morphology during the quiet geomagnetic condition (i.e. near the ground state of the magnetosphere). The average auroral precipitation pattern and its variation with interplanetary orientation are obtained; they provide the base line for understanding the solar-terrestrial interaction. Also the quiet time auroral morphology enlightens the nature of the polar cap aurora.

Relevant Publications

Meng, Ching-I., Diurnal variation of the auroral oval size and the minimum oval, J. Geophys. Res., 84, 5319, 1979.

Meng, Ching-I., Polar cap arcs and the plasma sheet, Geophys. Res. Lett., 8, 273, 1981.

Meng, Ching-I., Electron precipitations in the midday auroral oval, J. Geophys. Res., 86, 2149, 1981.

Meng, Ching-I., Auroral arcs observed by DMSP satellites, AGU Monograph, 25, Physics of Auroral Arc Formation, ed. by S.-I. Akasofu and J. R. Kan, p. 67, 1981.

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Linevsky, M. J., L. Monchick, C.-I. Meng, S. Chakrabarti and F. Paresce Some auroral properties from FUV observations, Planet. Space Sci., (submitted), 1983.

Makita, K., C.-I. Meng and S.-I. Akasofu, The shift of the poleward auroral oval boundary in the dawn-dusk sector in association with geomagnetic activity and interplanetary magnetic field, J. Geophys. Res., 88, 7967, 1983.

Meng, C.-I. and S.-I. Akasofu, Electron precipitation equatorward of the midday oval and the mantle aurora, Planet. Space Sci., 31, 889, 1983.

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Makita, K. and C.-I. Meng, Average electron precipitation patterns and visual aurora characteristics during geomagnetic quiescence, J. Geophys. Res., (in press), 1983.

Makita, K., C.-I. Meng, and S.-I. Akasofu, Temporal and spatial variations of the polar cap dimension and its relation to the energy input rate ϵ and AE index, J. Geophys. Res., (submitted), 1983.

III. SOURCE OF AURORAL ELECTRONS

The auroral oval is a permanent feature of the polar region as the consequence of the solar-terrestrial interaction. It has been thought that the auroral oval is the projection of the magnetospheric plasma sheet onto the polar ionosphere, and thus the electrons in the plasma sheet are likely to be a source of auroral electrons. The auroras also frequently occur at latitudes higher than the normal auroral oval location in the so-called polar cap regions where the geomagnetic field lines are expected to be open and topologically connected to the magnetotail lobe of very low plasma density. We have investigated these topics and obtain several protuberant results published in seven scientific articles listed below. The most important contributions which we made on this subject are: (1) The first conclusive observational evidence that diffuse auroral oval is the direct dumping of the plasma sheet electron by the strong pitch-angle-scattering, and (2) the majority of the so-called "polar cap" auroral arcs not really in the instantaneous polar cap proper but in the poleward part of the widened auroral oval during geomagnetic quiescence.

Relevant Publications

Meng, C.-I., Conjugate low energy electron observations made by ATS-6 and DMSP-32 satellites, AGU Geophysical Monograph Series, Vol. 21, Quantitative Modelling of Magnetospheric Processes, ed. by W. P. Olson, p. 96, 1979.

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Torbert, R. B., C. A. Cattell, F. S. Mozer and C.-I. Meng, The boundary of the polar cap and its relation to electric fields, field-aligned currents, and auroral particle precipitation, AGU Monograph, 25, Physics of Auroral Arc Formation, ed. by S.-I. Akasofu and J. R. Kan, p. 143, 1981.

Meng, C.-I. and S.-I. Akasofu, Electron precipitation equatorward of the midday oval and the mantle aurora, Planet. Space Sci., 31, 889, 1983.

Makita, K. and C.-I. Meng, Average electron precipitation patterns and visual aurora characteristics during geomagnetic quiescence, J. Geophys. Res., (in press), 1983.

IV. POLAR CAP DYNAMICS AND MAGNETOSPHERICAL CONFIGURATION

It is generally accepted by space physicists that the geomagnetic field lines originating from the polar cap extend into interplanetary space across the magnetopause and that the geomagnetic field lines originating from the auroral oval thread through the plasma sheet of the magnetotail. Thus the size and shape of the polar cap encircled by the auroral oval are significantly controlled by the interplanetary magnetic field orientation and the geomagnetic activity. The polar cap is enlarged when the interplanetary magnetic field has a strong southward directed component. Since the geomagnetic pole is offset from the geographic pole, the diurnal rotation of the earth should affect the configuration of the auroral oval as well. We have put in a significant amount of effort on this subject to investigate the interaction between the solar wind and the geomagnetic field. A total of 14 papers was published based on our study and listed below. The most significant achievements are: (1) The observation of the possible auroral oval shift associated with IMF B_x and B_y components, (2) The minimum size of the polar cap, (3) The diurnal variation of the auroral oval size, (4) The comparison between the observed and model calculation of the polar cap size and shape, and (5) Evolution of the auroral oval and polar cusp positions during intense geomagnetic storms.

Relevant Publications

Meng, Ching-I., Polar cap variations and the interplanetary magnetic field, <u>Dynamics of the Magnetosphere</u>, ed. by S.-I. Akasofu, D. Reidel Publishing Co., p. 23, 1979.

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Murphree, J. S., C. D. Anger, C.-I. Meng, and S.-I. Akasofu, Large-scale auroral distribution and the open field line region, Planet. Space Sci., (in press), 1983.

Meng, Ching-I., Case studies of the storm time variation of the polar cusp, J. Geophys. Res., 88, 137, 1983.

Makita, K., C.-I. Meng and S.-I. Akasofu, The shift of the poleward auroral oval boundary in the dawn-dusk sector in association with geomagnetic activity and interplanetary magnetic field, J. Geophys. Res., 88, 7967, 1983.

Holzworth, R. H. and C.-I. Meng, Polar cap motions with varying interplanetary magnetic field, Planet. Space Sci., (in press), 1983.

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Makita, K. and C.-I. Meng, Average electron precipitation patterns and visual aurora characteristics during geomagnetic quiescence, J. Geophys. Res., (in press), 1983.

Makita, K., C.-I. Meng, and S.-I. Akasofu, Temporal and spatial variations of the polar cap dimension and its relation to the energy input rate ε and AE index, J. Geophys. Res., (submitted), 1983.

V. POLAR CUSP MORPHOLOGY

The existence of a pair of neutral points on the dayside magnetopause was first discussed in 1931 and the calculated null points traced down to about 80°-83° geomagnetic latitude in both hemispheres. It has been also expected that solar wind, more explicitly magnetosheath particles, can gain direct entry into the inner magnetosphere from these neutral points (or lines). The actual existence of neutral magnetic field regions on the dayside magnetopause was confirmed by various satellites in 1972. Also confirmed was the entry of solar wind particles through these regions in the dayside magnetosphere at both low and high altitudes, by ISIS 1 and IMP 5 satellites, respectively. This region is now called the polar cusp or the dayside cleft, normally at ~ 76° gm lat. However, the spatial extent and dynamics of the polar cusp have not yet been completely understood. Furthermore, it is still controversial as to whether the magnetic null region on the dayside magnetopause forms a pair of points or lines. At the ionospheric level, recent observations and geometrical considerations indicate that the polar cusp has a 'spotlike' structure with a latitudinal width of several degrees and a longitudinal extent of only a few hours on either side of the noon meridian. Furthermore, the gap of discrete auroras in the dayside auroral oval seen near the noon meridian is likely to be the projection of the polar cusp on the ionosphere.

The latitudinal location of the dayside auroral oval was found to vary with geomagnetic activity suggesting the polar cusp location to vary as well. The polar cusp position indeed shifts equatorward with increasing geomagnetic activity, revealing the dynamic nature of the cusp region. From the topological consideration on the open magnetosphere, the equatorward

boundary of the polar cusp and the auroral oval delineates the region where the open field lines originate. The dynamical feature of the polar cusp latitude may indicate the interaction efficiency of the solar wind with the geomagnetic field and also changes of the magnetic energy stored in the magnetotail. It is generally accepted that the polar cusp shifts equatorward during times of a southward interplanetary magnetic field, but there have been some observations which contradict with such a general belief. The location of the polar cusp also responds to magnetospheric substorms in addition to the IMF. Some recent observations suggest that cusp movement is driven solely by variations of substorm magnetospheric current systems (represented by the AE index), and that the apparent correlation with IMF B_z result merely from an increased probability of substorms with the negative IMF B_z. It is important to note that previous cusp studies have used different signatures to identify the polar cusp region; this may introduce some inconsistency among the above-mentioned results. The polar cusp region at low altitude can be identified by measurements of various techniques, such as particle characteristics, wave characteristics, the magnetic field topology and the reversal of the ionospheric convections. It is important to emphasize that the spatial location and extent of the polar cusp may be different for different measurements; for example, the ions and protons in the polar cusp region are always distributed poleward of the polar cusp location identified from low-energy electron precipitation. Therefore the identification of the polar cusp is rather subjective depending on particular measurements.

Previous studies of the latitudinal variations of the polar cusp were based on mostly coincidental satellite observations of particle precipitations or the ground-based photometric and ionospheric measurements at certain high latitude ground stations with limited latitudinal and local time coverages of

the polar cusp observation. Statistically, it was found that an equatorial latitudinal shift of the polar cusp of about 5° corresponds to changes of IMF B from 6 nT to -6 nT, or to an increased AE index of ~ 800 - 1000 nT. The largest variation of the cusp position observed so far took place during a geomagnetic storm (Dst ≈ -90 nT) with a possible equatorward shift of about 10° from its normal location of ~ 76° gm lat to 66° gm lat. In order to understand the dynamics of the polar cusp region, a continuous monitoring of the polar cusp position (i.e., its motion) is necessary so that the history of its latitudinal shift during geomagnetic storms and moderate activities can be determined. However, such continuous observations are extremely difficult to perform because single-station ground-based measurements (such as by using all-sky cameras, meridional scanning photometers, or radars) only have an effective field of view at most about 5° - 7° in latitude and about 3-4 hours in local time (i.e., duration). A typical polar orbiting satellite cannot detect the polar cusp region more than twice per orbit in about 2 hours and usually less than once per orbit. Furthermore, geomagnetic storms last often more than 24 hours, and it is certain that only sporadic observations of the polar cusp location can be made by a single satellite during the development of an entire geomagnetic storm.

Among various techniques to monitor the polar cusp region, the best available way is by using several low-altitude satellites all on the noon-midnight polar orbit to perform the particle precipitation measurement. Fortunately, such opportunity indeed occurred in the USAF Defense Meteorological Satellite Program (DMSP). Two identical satellites had circular orbits in the noon-midnight meridian at ~ 840 km altitude, and the nearly 'continuous' observation of the polar cusp movement can be made by these satellites.

By using observations from DMSP satellites, we have found many morphologically and dynamically important features of the polar cusp region and six papers are published on this subject. The most significant results are: (1) A more precise identification of the cusp region, (2) the large scale dynamical movement of the cusp during intense magnetic storms, (3) the first simultaneous observation of the conjugate polar cusp regions, and (4) the comparison between the solar wind density and the polar cusp plasma density.

Relevant Publications

Meng, Ching-I., Electron precipitations in the midday auroral oval, J. Geophys. Res., 86, 2149, 1981.

Meng, Ching-I., Latitudinal variation of the polar cusp during a geomagnetic storm, Geophys. Res. Lett., 9, 60, 1982.

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Candidi, M. and. C.-I. Meng, The relation of the cusp precipitating electron flux to the solar wind and interplanetary magnetic field, J. Geophys. Res., (submitted), 1983.

VI. MAGNETOSPHERIC MORPHOLOGY AND MISCELLANEOUS

The configuration of the magnetosphere is controlled by the solar wind, the interplanetary magnetic field and the distribution of plasmas and electric currents in the magnetosphere. Their combined effects divide the magnetosphere into two basic regions, the so-called closed-field region and the open-field region. The auroral oval delineates approximately the boundary of the two regions at the ionsopheric level. Changes of this boundary and thus of the auroral oval indicate major changes of the internal structure of the magnetosphere as a response to changes of the solar wind and the IMF as mentioned in Section IV.

The magnetosphere intermittently undergoes a fairly systematic alteration called the magnetospheric substorm, of which the auroral substorm is a part. It is useful to discuss the crude analogy between a cathode ray tube and the magnetosphere in illustrating the importance of auroral display in magnetospheric studies. In Figure 1, the screen of the tube corresponds to the polar upper atmosphere, and an image on the screen corresponds to the auroral display. Various modulating devices in the tube cause the electron beam to move and produce the image on the screen. Similarly, auroral activity indicates complex disturbances of the electric and magnetic fields in the magnetosphere. It has been one of the most important tasks for space physicists to find (a) how the magnetosphere is powered (i.e. the solar wind - magnetosphere interaction); (b) what is the mechanism analogous to the electron gun and beam (i.e. the acceleration mechanism of auroral electrons), and (c) how the electron beam is modulated (i.e. the magnetospheric storm). Auroral imagery and electron data from DMSP provide the needed information.

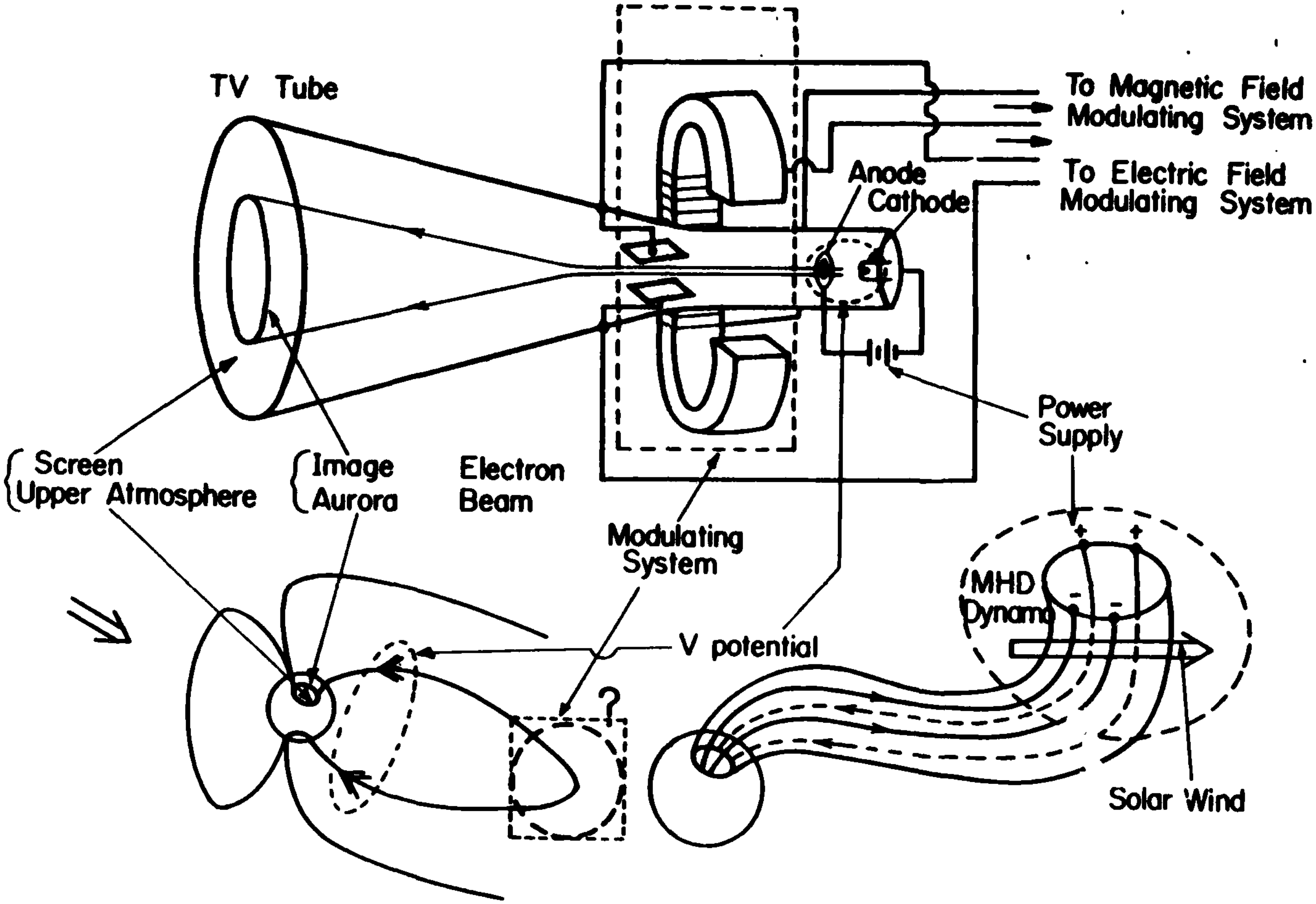

Fig. 1 A schematic diagram to illustrate the analogy between the television tube and the magnetosphere. The auroras in the polar upper atmosphere are produced by the bombardment of electron beams, in great similarity with images on a TV screen. The electromagnetic state in the magnetosphere plays the role of modulating the electron beams like the electric plate and electromagnet within the TV tube. It is believed by some magnetospheric physicists that the power for the auroral phenomenon is derived from the MHD dynamo action of solar wind blowing across the "open" geomagnetic field lines, and the acceleration mechanism for the electron beams is the V-potential along geomagnetic field lines.

In addition, other satellites at higher altitude in the magnetosphere are used for this purpose. We also examined the energy input and the energy dissipation of the magnetosphere.

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Mauk, B. H., Electromagnetic wave energization of heavy ions by the electric "phase bunching" process, Geophys. Res. Lett., 9, 1163, 1982.

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VII. SUMMARIES OF PUBLISHED RESULTS

During the period of the Air Force Office of Scientific Research Grant AFOSR-79-0010, we have made many significant progress in investigating the polar auroral display and electron precipitations as well as their corresponding magnetospheric dynamics. All of these research results are eventually published in the form of scientific papers by prominent international journals. There are 34 of them either already or in the process to be published. Certainly a complete collection of these research results would be an ideal final scientific report and the size of the report will be over 400 printed pages. Since all the papers are already published by the widely-circulating journals, there is no reason to waste valuable research resources just to duplicate and bind them into one volume. Thus, in this final report only the summary of each publication is given and it forms a concise digest of the accomplishments under this Grant. Details of each result can be found in the original publications. Summaries are ordered chronologically in the following.

(1) Conjugate Low Energy Electron Observations Made by ATS-6 and DMSP-32 Satellites, by C. I. Meng, <u>AGU Geophysical Monograph Series</u>, <u>21</u>, <u>Quantitative Modelling of Magnetospheric Processes</u>, ed. by W. P. Olson, p. 96, 1979.

Coordinated simultaneous observations of low energy electrons at conjugate locations by using two satellites are presented. The geosynchronous ATS-6 measures the plasma sheet electrons near the magnetospheric equator, and the polar-orbiting DMSP-32 measures the the auroral electron preci-

pitation above the ionosphere. It is found that the particle characteristics of precipitated auroral electrons of diffuse auroras in the evening sector are nearly identical to those of the trapped plasma sheet electrons in the conjugate magnetospheric equator. This property of conjugate electrons reveals that the conjugate latitude of ATS-6 in the evening sector is at about 65.7° corrected geomagnetic latitude.

(2) Polar Cap Variations and the Interplanetary Magnetic Field, by C. I. Meng, in Dynamics of the Magnetosphere, ed. by S. I. Akasofu, D. Reidel Publishing Company, p. 23, 1979.

This paper reviews research involved with direct and inferred determinations of the polar cap size and location, as well as their relationships with the interplanetary magnetic field. "Polar cap" is defined here as the region of open geomagnetic field lines encircled by the auroral oval. The first part of the paper reports the progress in the observation and understanding of polar cap size variations as related to changes of the interplanetary magnetic field magnitude and direction obtained by scaling the global auroral distributions from DMSP auroral pictures. Some new results on configurational changes of the auroral oval (i.e., the polar cap) with different orientations of the interplanetary magnetic field are also discussed. There are indications of the dawn-dusk and sunward-tailward displacements of the auroral oval in association with the interplanetary magnetic field B_y and B_x components, respectively. It is obvious i om

this review that a better understanding of the interaction between the terrestrial magnetosphere and the interplanetary magnetic field requires further efforts, both observational and theoretical.

(3) Electron Precipitation of Evening Diffuse Aurora and Its Conjugate Electron Fluxes Near the Magnetospheric Equator, by C.-I. Meng, B. Mauk and C. E. McIlwain, J. Geophys. Res., 84, 2545, 1979.

A more precise and definitive relation between diffuse auroras and their particle source region was determined by examining simultaneously the particle observations at the geosynchronous orbit and the auroral display as well as the auroral electron precipitations near its field line conjugate observed by the polar-orbiting DMSP 32 satellite. It is found that the spectral shape and differential fluxes of precipitated auroral electrons of diffuse auroras are very similar, and sometimes almost identical, to those of the trapped plasma sheet electrons located simultaneously in the conjugate magnetospheric equator. The characteristics of auroral electron precipitations are determined by the particle features in the conjugate magnetospheric equator, and diffuse auroras are produced by the direct dumping of the plasma sheet electrons.

(4) Diurnal Variation of the Auroral Oval Size, by C.-I. Meng, J. Geophys. Res., 84, 5319, 1979.

An examination of the equatorial boundary of the auroral oval (as defined by quiet-time auroral electron precipitations) reveals a periodic variation of its latitudinal location. The period of oscillation is 24-hours and the amplitude is about 4°. This diurnal variation seen in the evening and morning sectors of the auroral oval is in phase as is in the diurnal variation of the northern and southern hemispheres. The observed latitudinal variation is attributed to UT diurnal variation of the auroral oval size in association with the daily precession of the geomagnetic pole. The auroral oval is smaller when the northern geomagnetic pole is near the local midnight around 0600 UT; it is larger when the northern geomagnetic pole is near the local noon around 1800 UT. The equatorial edges of the evening sector of the quiet auroral oval (1900-2100 MLT) are located at about 72° and 69° CGL, respectively, which correspond to the minimum auroral oval.

(5) Relevance of Southward Magnetic Fields in the Neutral Sheet to Anisotropic Distribution of Energetic Electrons and Substorm Activity, by A. T. Y. Lui and C.-I. Meng, J. Geophys. Res., 84, 5817, 1979.

The implications of southward magnetic fields at the magnetotail neutral sheet to the development of streaming anisotropy of energetic electrons and magnetospheric substorm

activity are examined. Magnetic field and energetic particle measurements from the Imp 6 spacecraft, the AE index, and global auroral images from DMSP spacecraft are utilized in this study. Criteria are developed to identify events of southward magnetic fields at the neutral sheet which imply the presence of X-type magnetic neutral lines. Several features of the observations suggest that the southward magnetic fields and the implied X-type neutral lines are associated with magnetic bubbles in the neutral sheet region. It is found that the signatures of magnetic bubbles are sometimes detected in association with tailward streaming and flux enhancement of energetic electrons (47 keV < E < 350 keV). A cigar-shaped anisotropy in the energetic electron distribution is frequently but not always observed before the onset of tailward streaming of energetic electrons. The tailward streaming is magnetic field-aligned and occurs in the form of bursts, suggesting that the generating process is activated somewhat quasi-periodically and is not in a steady state. Signatures of magnetic bubbles are also detected without any substantial enhancement of detectable tailward streaming of energetic electrons. By comparing Imp 6 observations with AE index and global auroral images from DMSP spacecraft, it is found that signatures of magnetic bubbles in the neutral sheet are observed during substorms as well as during quiet geomagnetic conditions, indicating that magnetic bubbles are intrinsic features of the neutral sheet in the magnetotail regardless of substorm activity.

(6) Reply of comment on "Diurnal variation of the auroral oval size", by C.-I. Meng, J. Geophys. Res., 85, 2375, 1980.

Comments by Gussenhoven et al. (1980) raise the question of whether the observed latitudinal shift of the equatorial precipitation boundary of auroral oval detected by dawn-dusk DMSP satellites is an artifact of the diurnal variation in the satellite's trajectory with respect to the geomagnetic coordinate system. They suggested that in order to determine the UT variation of the auroral oval (1) a correction should be made to this trajectory variation or (2) only data from a limited local time sector be used. It was assumed in their analysis that the equatorward precipitation boundary of the instantaneous auroral oval forms a circle with its center at about 4° along the 0100 MLT meridian. This assumption needs justification since the poleward boundary rather than the equatorward boundary of the instantaneous auroral oval has been fitted to a circle. It is also uncertain how the circle shown in Figure 3 of Gussenhoven et al. (1980) was determined, since the circle was chosen to fit only two points (the morning and evening values of Λ_E for the first pass). Thus, either the radius of the circle or the center location of the circle was pre-assumed in their fitting process.

The problem of trajectory variation as a function of UT was considered in Meng (1979), and the scheme to reduce this effect involved selecting DMSP observations over only 2 hours magnetic local time meridian in the evening sector. If the

equatorward boundary of the instantaneous auroral oval forms a circle centered at about 4° away from the pole along the midnight meridian similar to the poleward edge of the quiet discrete auroral arcs described by Meng et al. (1977), then the maximum possible latitudinal difference between 19 and 21 magnetic local times is about 2° as shown by Gussenhoven et al. (1980). However, this hypothetical latitudinal variation of about 2° or less in association with the orbital motion cannot satisfactorily explain the approximately 4° in the observed diurnal variation of the auroral oval latitude. In order to eliminate the orbital effect, their one suggestion of making a correction to measurements at different local times requires knowledge of the exact instantaneous auroral oval distribution which was not available (as mentioned in the original paper). The other correction, based on an "assumed" circular shape of the instantaneous auroral oval distribution, is undesirable due to the variability of the instantaneous oval configuration under different interplanetary and magnetospheric conditions. Finally, I would like to point out that results of two statistical analyses of auroral oval Q index and the oval latitude near midnight meridian are consistent with the diurnal variation of the auroral oval size. These analyses were discussed in the original paper (Meng, 1979) and are free of the orbital effect discussed by Gussenhoven et al. (1980).

References

Gussenhoven, M. S., D. A. Hardy, and W. J. Burke, Comments on "Diurnal Variation of the Auroral Oval Size" by C.-I. Meng, J. Geophys. Res., (this issue), 1980.

Meng, C.-I., Diurnal Variation of the Auroral Oval Size, J. Geophys. Res., 84, 5319, 1979.

Meng, C.-I., R. H. Holzworth, and S.-I. Akasofu, Auroral Circle Delineating the Poleward Boundary of the Quiet Auroral Belt, J. Geophys. Res., 82, 164, 1977.

(7) Electron Precipitation in the Midday Auroral Oval, by C.-I. Meng, J. Geophys. Res., 86, 2149, 1981.

Simultaneous observations of auroral displays and electron precipitations by the DMSP 33 satellite provide an excellent and unique opportunity to study precipitation characteristics of the midday auroral oval. Attention is given to two topics: (1) the nature of the "gap" of the midday discrete auroras which is a permanent feature of the dayside auroral oval observed by both Isis 2 and DMSP satellites and (2) the relationship of this gap with the polar cusp region. Based on 2-month (June, July 1975) observations of the midday auroras over the southern hemisphere, it is found that inside the "gap" of the discrete auroras along the dayside auroral oval, soft electron precipitations with a

magnetosheathlike spectrum were invariably detected. The spatial extent of this region was about few degrees in latitude and about 2-3 hours in local time near 1130 magnetic local time meridian. No significant electron precipitation was detected poleward of the instantaneous midday auroral oval. Typical plasma sheet and discrete auroral types of electron precipitations were detected in the other parts of the midday auroral oval. Therefore it is proposed that the ionospheric projection of the polar cusp is a small region of the instantaneous dayside auroral oval near the noon meridian, coinciding with the "gap" of the midday discrete auroras.

(8) The Auroral Electron Precipitation During Extremely Quiet Geomagnetic Conditions, by C.-I. Meng, J. Geophys. Res., 86, 4607, 1981.

The electron precipitation over the polar regions during extremely quiet geomagnetic conditions is examined based on data from 5 years of DMSP observations. A total of 12 periods were selected for this study on the basis of prolonged, extremely low values of the Kp index which persisted for at least 2 consecutive days. The interesting electron precipitation features can be summarized as follows: (1) At all times, precipitation indeed occurred over both the northern and southern polar regions with significant intensity. The precipitating intensities were 1-2 orders of magnitude below the level for nominal, quiet ($Kp \lesssim 2$) auroral oval precipitations. (2) The measured precipitating electrons were very soft, most having energies below 1 keV. The observed fluxes

of low-energy electrons between 50 eV to a few hundred eV were often merely the high-energy tail of an extremely soft precipitation. (3) Electron precipitation with a most probable energy of a few keV (harder than that of the auroral oval) can form a band detached from and equatorward of the morning auroral oval. (4) A dramatic feature of the electron precipitation of the extremely quiet magnetosphere is the unexpectedly wide latitudinal extent of the low-energy electron precipitation. It spreads into the high-latitude polar regions to at least $\sim 85°$ geomagnetic latitude.

(9) Polar Cap Arcs and the Plasma Sheet, by C.-I. Meng, Geophys. Res. Lett., 8, 273, 1981.

This letter suggests that most of the so-called "polar cap arcs" with the sun-aligned orientation at the high geomagnetic latitude region occurring during the quiescent magnetosphere are actually a part of discrete arcs in the auroral oval as a consequence of the poleward widening of the quiet auroral oval. This suggestion is based on (1) a detailed examination of two months of DMSP electron precipitations data and simultaneous auroral observations, (2) the observed widening in the latitudinal extent of the auroral oval precipitation to the very high geomagnetic latitude ($\gtrsim 80°$) and the simultaneous occurrence of the sun-aligned arcs, and (3) the conjugate widening of the quiet auroral oval over both the northern and southern polar regions. The new

interpretation of the "polar cap arcs" is discussed in terms of the present understanding of the solar wind-magnetospheric interaction.

(10) Temperature Variation of the Plasma sheet During Substorms, by A. T. Y. Lui, C.-I. Meng, L. A. Frank, K. L. Ackerson and S.-I. Akasofu, Planet. Space Sci., 29, 837, 1981.

The temperature and density of the plasma in the Earth's distant plasma sheet at the downstream distances of about 20-25 R_e are examined during a high geomagnetic disturbance period. It is shown that the plasma sheet cools when magnetospheric substorm expansion is indicated by the AE index. During cooling, the plasma sheet temperature, T, and the number density, N, are related by $T \propto N^{2/3}$ (adiabatic process) in some instances, while by $T \propto N^{-1}$ (isobaric process) in other cases. The total plasma and magnetic pressure decreases when $T \propto N^{2/3}$ and increases when $T \propto N^{-1}$. Observation also indicates that the dawn-dusk component of plasma flow is frequently large and comparable to the sunward-tailward flow component near the central plasma sheet during substorms.

(11) Dependence of the Geometry of the Region of Open Field Lines on the Interplanetary Magnetic Field, by S.-I. Akasofu, D. N. Covey and C.-I. Meng, Planet. Space Sci., 29, 803, 1981.

The geometry of the open flux area in the polar region is computed by superposing a uniform interplanetary magnetic field (IMF) with various orientation angles to a model of the magnetosphere. It is confirmed that the IMF B_y component is as important as the B_z component in "opening" the magnetosphere. It is also shown that the computed area of open field lines is remarkably similar to the observed ones which were determined by using the entry of solar electrons. In particular, when the IMF vector is confined in the X-Z plane and the B_z component has a large positive value, the open area becomes crescent-shaped, coinciding approximately with the cusp region.

(12) Auroral Arcs Observed by DMSP Satellites, by C.-I. Meng, Physics of Auroral Arc Formation, ed. by Akasofu and Kan, p. 67, 1981.

This paper reports the electron precipitation characteristics of discrete auroras distributed over various parts of the polar region, based on the simultaneous optical auroral display observations and the electron precipitation measurements made by the DMSP series of satellites. It was found that all discrete arcs have a common feature, namely the existence of a peak in the electron differential energy spectra. The location of this spectral peak and the preci-

pitated energy flux differs with the auroral brightness and geomagnetic activity. The precipitated energy flux varies from f10 erg $cm^{-2}sec^{-1}sr^{-1}$ for bright active arcs, $\sim$ 1-2 erg $cm^{-2}sec^{-2}sr^{-1}$ for normal quiet arcs to a fraction of 1 erg $cm^{-2}sec^{-1}sr^{-1}$ for faint arcs. The spectral peak is at $\gtrsim$ 8 keV for bright active arcs, $\sim$ 3 for normal arcs and $\lesssim$ 1 keV for faint arcs.

(13) The Boundary of the Polar Cap and Its Relation to Electric Fields, Field-Aligned Currents, and Auroral Particle Precipitation, by R. B. Torbert, C. A. Cattell, F. S. Mozer and C.-I. Meng, <u>AGU Geophysical Monograph Series</u>, <u>25</u>, <u>Physics of Auroral Arc Formation</u>, ed. by S.-I. Akasofu, and J. Kan, 1981.

Simultaneous observations of electric fields, field-aligned currents, and auroral particles on the S3-3 spacecraft over the earth's polar regions have been used to illustrate how the low-altitude extent of field lines open to interplanetary space may be unambiguously identified. We define the polar cap to be the region of open field lines, which are only those containing plasma flowing anti-sunward and possessing precipitating low-energy electron distributions characteristic of the magnetosheath. Field-aligned current signatures are found near the polar cap boundary, but not always coincident with it. Within this polar cap, gradients in the observed soft particle flux are explained as a result of the density decrease previously observed in the magnetosheath as one progresses anti-sunward along the magnetotail.

Presumably depending upon the interplanetary magnetic field orientation, the location of the polar cap is occasionally drastically shifted. At these times, there are high-latitude regions, extending even up to the magnetic pole, which are closed and convecting towards the sun. Since boundaries, identified by either the poleward extent of plasma sheet particle populations or the 33 keV electron intensity cutoff or isotropy boundary, are well-separated at these times from the region of open field lines, we conclude that there is no physical connection between these boundaries and the edge of the polar cap; but, rather, that they are topologically often found near each other. The location of field-aligned current sheets appears to depend, in a more complex way, on the gradients in the electric field and ionospheric conductivity, as indicated by auroral precipitation.

(14) Large Amplitude Undulations on the Equatorward Boundary of the Diffuse Aurora, by A. T. Y. Lui, C.-I. Meng and S. Ismail, J. Geophys. Res., 87, 2385, 1982.

Global auroral pictures from the Defense Meteorological Satellite Program (DMSP) satellites are presented to show, for the first time, occurrences of large amplitude undulations on the equatorward boundary of the diffuse aurora in the afternoon-evening sector. The crest-to-trough amplitude of these waveforms ranges from about 40 to 400 km and the wavelength varies from about 200 to 900 km. the undulations are seen in one case to extend over 3000 km along the equatorward

boundary. Auroral images from successive DMSP passes suggest that this phenomenon lasts for about 0.5 to 3.5 hours. In each of the four cases observed, the undulations occur during a geomagnetic storm interval near the peak development of the storm time ring current. In all instances, auroral pictures displaying the undulations show simultaneous substorm patterns of discrete auroras. In one instance when simultaneous electron (50 eV to 20 keV) measurements from DMSP satellite are available, the electron spectra near the diffuse auroral equatorward boundary resemble power law spectra, and the scale length for the density gradient at the boundary is determined to be about 12 km. Weak electron precipitation is also found equatorward of the diffuse aurora and the associated electron spectra frequently show a secondary population with peak fluxes at 1-5 keV. The observed undulations are interpreted as surface waves propagating on the inner edge of the plasma sheet, and possible plasma instabilities responsible for it are briefly discussed.

(15) Latitudinal Variation of the Polar Cusp During a Geomagnetic Storm, by C.-I. Meng, Geophys. Res. Lett., 9, 60, 1982.

Large amplitude latitudinal variation of the polar cusp position was observed during the intense geomagnetic storm of 15-16 February 1980. The observation of the polar cusp, identified as the region of intense but extremely soft electron precipitation, was made by two nearly noon-midnight orbit DMSP satellites over both northern and southern hemi-

spheres. The latitudinal shift of the polar cusp is observed to be related to the intensity variation of the ring current indicated by the hourly Dst values. The polar cusp region moved from its normal location at ~ 76° gm lat down to ~ 62° gm lat at the peak of this storm. This movement took about 5 hours and was detected over both hemispheres. A drastic variation in the width of the cusp region was also observed; it is very narrow (~ 1°) during the equatorial shift and expands to $\gtrsim$ 5° during the poleward recovery. Variation of the polar cusp latitude with that of the Dst index was also seen during the period before the intense storm.

(16) A Classification of Polar Cap Auroral Arcs, by S. Ismail and C.-I. Meng, Planet. Space Sci., 30, 319, 1982.

Global auroral imagery obtained by DMSP satellites during the years 1972-1979 over both the northern and southern high latitude polar regions were examined to study the morphology of the discrete arcs known as polar cap arcs. Based upon their morphology, the polar cap arcs can be generally classified into three types viz. (1) the distinctly sun-aligned polar cap arcs - Type 1 arcs, (2) the morning/evening polar cap arcs expanded from the auroral oval - Type 2 arcs and (3) the hook shaped arcs connecting the polar cap arc with the oval arc (including the hitherto unreported oppositely oriented hook shaped arcs) - Type 3 arcs. Concurrent auroral electrojet indices (AE) and interplanetary magnetic field (IMF) data were used to study the occurrence of the polar cap

arcs. It was found the Type 1 arcs were observed mostly during low geomagnetic activity conditions, bright Type 2 arcs during the recovery phase of the substorms and Type 3 arcs do not occur during the recovery phase of the substorm. Over both hemispheres, the polar cap arcs were observed mostly during northward IMF. Furthermore, Type 1 arcs were observed over the northern polar cap during mostly negative B_x periods and over the southern polar cap during mostly positive B_x periods. The latter observation suggests that these types of arcs may be non-conjugate.

(17) Electromagnetic wave energization of heavy ions by the electric "phase bunching" process, by B. H. Mauk, Geophys. Res. Lett., 9, 1163, 1982.

Magnetic "wave trapping" and what is termed here electric "phase bunching" are shown to be the high and low energy behaviors which result when a magnetized heavy ion interacts with a nearly resonant electromagnetic cyclotron wave. The properties of electric "phase bunching" are explored by computer simulation. Because these properties match observations it is concluded that the strongly cyclotron phase bunched and energized helium ions, observed in association with waves in the earth's geostationary magnetosphere, are generated by this electric "bunching" process.

(18) A High Time Resolution Study of the Solar Wind-Magnetospheric Energy Coupling Function, by S.-I. Akasofu, J. F. Carbary, C.-I. Meng, J. P. Sullivan and R. P. Lepping, Planet. Space Sci., 30, 537, 1983.

A high time resolution study of the relationship between the solar wind-magnetosphere energy coupling function ε and the total energy dissipation rate U_t of the magnetosphere is made using 5-min average values of solar wind data and of the geomagnetic indices AE and Dst. All the results are essentially the same as those obtained by the earlier studies which were based on the hourly average data set. Therefore, we confirm that the magnetosphere is primarily a driven system.

(19) Large-Scale auroral distribution and the open field line region, by J. S. Murphree, C. D. Anger, C.-I. Meng, and S. I. Akasofu, Planet. Space Sci., in press, 1983.

An example of a global auroral distribution is presented which is clearly more circular than oval and is thus fit to an offset circle. The area surrounded by the aurora is also compared with the open region constructed by a model of the open magnetosphere for the IMF condition about 1 hour prior to the auroral observation.

(20) Some auroral properties from FUV observations, by M. J. Linevsky, L. Monchick, C.-I. Meng, S. Chakrabarti, and F. Paresce, Planet. Space Sci., (submitted), 1983.

Recent far ultraviolet spectra of four nightside auroras observed with the EUV spectrometer aboard P78-1 satellite are analyzed here in terms of a secondary electron flux distribution model. Using the 1084 Å NII line as the norm, the relative intensities of several lines in the range 900 Å to 1400 Å can be fit by the model allowing an estimate of the lowest depth of penetration of the secondary electron flux and the total energy deposition by the primary flux.

(21) Case studies of the storm time variation of the polar cusp, by C.-I. Meng, J. Geophys. Res., 88, 137, 1983.

The latitudinal variations of the polar cusp region were examined during three intense geomagnetic storms. The variations were compared with the intensity of storm time ring current inferred from the Dst index, with the magnitude of the north-south component B_z of the interplanetary magnetic field and with substorm activity. The common feature is that the rapid equatorward shift occurred during the increase of the ring current growth and during the southward turning of the interplanetary magnetic field orientation. The equatorward most latitude of the cusp was reached before the peak of the ring current intensity, by a few to several hours, coinciding with the occurrence of the largest magnitude of the southward

interplanetary magnetic field component. However, details of the polar cusp latitudinal movement differ from storm to storm. During the three storms studied, the poleward recovery commences at the peak magnitude of the negative IMF B_z component, but the recovery proceeded without a clear relation to variations of the interplanetary B_z component, to the ring current intensity, or to the substorm activity. The lowest cusp latitude observed was at ~ 61.7 °, and the magnitude of this shift seems to be related to the magnitudes of $-B_z$. It is further observed that the approximate rates of the cusp macroscopic equatorward and poleward movements are about 3° and 1.5° per hour, respectively.

(22) The shift of the poleward auroral oval boundary in the dawn-dusk sector in association with geomagnetic activity and interplanetary magnetic field, by K. Makita, C.-I. Meng and S.-I. Akasofu, J. Geophys. Res., 88, 7967, 1983.

On the basis of the auroral precipitating electron data along the dawn-dusk meridian from a Defense Meteorological Satellite Program satellite (DMSP-F2), we show that the electron precipitation region extends poleward, often to the geomagnetic latitudes $\gtrsim$ 85° from the average oval location, during quiet periods (namely, during periods of a large positive B_z component). This result may be interpreted as an indication that only a small amount of geomagnetic flux interconnect with the northward IMF, resulting in a contracted "open" region (the polar cap). The control of the location of

the poleward boundary by the north-south component of the IMF is also statistically examined. The rate of latitudinal movement is about 0.4° to 0.8° per 1 nT for positive IMF B_z values and about 0.7° to 1.1° per 1 nT for negative IMF B_z values. The shift of the equatorward boundary is not obvious, however, for positive IMF B_z values. As geomagnetic activity increases, both the poleward and equatorward boundaries shift toward lower latitudes. The equatorward shift of the poleward boundary is greater than that of the equatorward boundary, resulting in a thinner electron precipitation region during disturbed periods than during quiet periods.

(23) Polar cap motions with varying interplanetary magnetic field, by R. H. Holzworth, and C.-I. Meng, Planet. Space Sci., (in press), 1983.

This paper describes a DMSP data set of 150 auroral images during magnetically quiet times which have been analyzed in corrected geomagnetic local time and latitudinal coordinates and fit to offset circles. The fit parameters R(circle radius) and (X, Y) (center location) have been compared to the hourly interplanetary magnetic field (IMF) prior to the time of the satellite scan of the aurora. The results for variation of R with B_z agree with previous works and generally show about a 1° increase of R with increase of southward B_z by 1 nT. The location of the circle center also has a clear statistical shift in the southern hemisphere with IMF B_y such that the southern polar cap moves towards dusk (dawn) with $B_y > 0$ ($B_y < 0$).

(24) Spatial intensity of dayside polar soft electron precipitation and the IMF, by M. Candidi, H. W. Kroehl and C.-I. Meng, Planet. Space Sci., 31, 489, 1983.

The influence of the B_z and B_y polarity of the IMF on the location of the dayside regions of precipitating, low-energy electrons recorded by DMSP F-2 satellite, is investigated. The average differential electron flux was determined for two months during local summer. It is found that the spatial distributions are similar for electrons in the range from 50 eV to 183 eV. The region of maximum intensity for $K_p \leq 2+$ over the Southern Hemisphere is located on the opposite side of noon from the Northern Hemisphere. The current intensity carried by precipitating electron in the cleft region agrees with that measured by the Triad magnetometer. When the IMF is northward a marked asymmetry of the low-energy electron precipitation between positive and negative B_y cases is observed. For positive B_y the maximum electron flux occurs between 0800-1200 MLT and -76° to -83° MLAT and for negative B_y the region occurs between 1200-1500 MLT and -79° to -82° MLAT. The dynamical variations associated with substorm activity when the IMF is southward obscure the expected B_y effect.

(25) Characterization of geostationary particle signatures based on the "injection boundary" model, by B. H. Mauk and C.-I. Meng, J. Geophys Res., 88, 3055, 1983.

To lend further support to the "injection boundary" concept, this paper characterizes the details of geostationary particle signatures using a very simple-minded analysis procedure. The signatures are generated using the time of flight effects which evolve from an initial sharply defined, double-spiraled boundary configuration. By using only the most fundamental characteristics of standard convection configurations, the very complex and highly variable dispersion patterns frequently observed by geostationary satellites are successfully reproduced. In particular, seven distinctly different ion-electron paired dispersion patterns on energy versus time spectrograms (1 eV to 100 KeV) are predicted, and all seven of these are observed on a regular basis by both the SCATHA satellite (in the near geostationary orbit) and the ATS-6 satellite. Many of the details of the patterns have not been previously presented. It is concluded that most dynamical dispersion features (including energetic ion and electron echoes) can be mapped to the double-spiral boundary without further ad hoc assumptions. It is shown further that the predicted and observed dispersion patterns have symmetries which are distinct from the symmetries generally associated with the quasi-stationary particle convection patterns.

(26) Nearly simultaneous observations of the conjugate polar cusp regions, by M. Candidi and C.-I. Meng, Planet. Space Sci., (in press), 1983.

This paper reports the first nearly simultaneous observations of precipitating electrons in the conjugate low altitude polar cusp regions. In two cases the DMSP-F2 and F4 satellites observe the cusp regions within the same geomagnetic local item sector over the opposite hemispheres. The electron spectra are identical in the conjugate cusps. In one case the observed latitudinal location and extent of the cusps are the same at opposite hemispheres; the northern and southern cusp regions overlap with the plasma sheet electron precipitation regions at lower latitude; the poleward boundary of these overlapping regions is located at the same latitude on either hemisphere, suggesting that this is the latitude of the last closed field line; this implies that the cusp electrons are present on both closed and open magnetic field lines. In the other case the location of the equatorward boundary of the cusp regions differs from one hemisphere to the other and on plasma sheet electrons are observed. The slight time difference between the conjugate observations of the cusps (less than six minutes) is sufficient to introduce space/time ambiguities.

(27) Electron precipitation equatorward of the midday oval and the mantle aurora, by C.-I. Meng and S.-I. Akasofu, Planet. Space Sci., 31, 889, 1983.

In the midday sector, the hard electron precipitation and the associated patchy aurora at geomagnetic latitude ~ 65 ° are the only auroral features ($\lesssim$ 20 keV) located equatorward of the dayside auroral oval during intense and moderately disturbed geomagnetic conditions. We identify the patchy luminosity in the midday and late morning sectors as the active mantle aurora. The mantle aurora was found by Sanford in 1964 using the IGY-IGC auroral patrol spectrographs and which was thought to be non-visual. The precipitating electrons reside mostly at energies greater than several keV with an energy flux of $\gtrsim 0.1$ erg $cm^{-2}s^{-1}sr^{-1}$ during geomagnetic active periods. This hard precipitation occurs in a region which is asymmetric in L.T. with respect to the noon meridian. The region extends from the morning sector to only early afternoon (13-14 M.L.T.) along the geomagnetic latitude circle of about 65-70°. The model calculation indicates that the mantle aurora is produced by the precipitation of the energetic electrons which drift azimuthally from the plasma sheet at the midnight sector to the dayside magnetopause during magnetospheric substorms.

(28) Comparison of the auroral electron precipitations in the northern and southern conjugate regions by two DMSP satellites, by K. Makita, C. -I. Meng, S. -I. Akasofu, Memoirs of National Institute of Polar Research, No. 26, p. 149, Japan, 1983.

The electron precipitation in the northern and southern conjugate regions, observed by the DMSP-F2, F3 and F4 satellites, is examined. The high energy auroral electron precipitation region (the average energy higher than 500 eV and the number flux greater than 10^7 electrons/cm^2 s sr) during quiet periods are somewhat different in the opposite hemispheres. Some of the differences seem to be controlled by the interplanetary magnetic field.

(29) Dynamic variation of the auroral oval during intense magnetic storms, by C. -I. Meng, J. Geophys. Res., in press, 1983.

The latitudinal variations of the noon sector polar-cusp region and the nightside auroral oval were examined to investigate the auroral oval dynamics during three intense geomagnetic storms. The variations were compared with the variation in ring-current intensity (i.e., Dst) and with changes of the interplanetary magnetic field B_z component to determine the dominant parameter of the large-scale polar region configuration changes during magnetic storms. Deviations of the polar cusp and the midnight auroral oval from their normal quiet time position are also compared to determine the occurrence of the large-scale reconfiguration of the polar-

region geometry. It is found that (a) the large (>10° geomagnetic latitude) equatorial shift of the auroral oval occurs in coordination with the equatorward motion of the polar-cusp region; (b) the polar cusp is displaced by a few degrees more than the nightside auroral oval near the peak of a magnetic storm; (c) the midnight auroral oval recovers more slowly than the polar-cusp region during the storm recovery phase; and (d) the midnight oval and the noon sector polar-cusp region move coherently with the southward variation of the interplanetary magnetic field B_z but not necessarily with the Dst intensity variations.

(30) Dynamical injections as the source of near geostationary, quiet-time particle spatial boundaries, by B. H. Mauk and C. -I. Meng, J. Geophys. Res., 88, 10011, 1983.

To test our understanding of quasi-stationary magnetospheric particle convection, we address here a particular class of particle feature (plasma drop-outs at 0 eV to 5 keV) observed regularly by near geostationary satellites in the noon to dusk quadrant, often during the apparent absence of recent (hours) substorm activity. At first consideration the feature appears to result from the passage of the satellites towards and into the so-called "forbidden zone" of the quasi-stationary particle convection patterns. It is demonstrated here that the energy dispersion of the feature cannot be explained by simple stationary convection models even when loss processes are imposed on those particles which penetrate most

closely to the earth. Also, the radial position of the feature does not vary with geomagnetic activity as expected from steady convection models. It is concluded that dynamical processes are responsible. However, models based on the modification of the so called cross-tail field configuration against initial stationary convection patterns are rejected here because these models preserve the qualitative sense of the energy dispersions of the initial pattern. It is proposed that the spatial structures of past (24 hours), dynamical, night-side particle injections determine to a great extent the character of the feature. It is shown that detailed simulations based on the double-spiraled "injection boundary" concept (used previously to reproduce the fast changing night-time features) reproduce very well the character and dispersion senses of the noon-to-dusk feature by allowing the distributions to evolve for many hours. It is emphasized that the portion of the original injection boundary which gives rise to this feature of interest is the decidedly "non-Alfvenic" portion. Taking into account the predominance of the feature, it is concluded that the geostationary regions ($r \lesssim 8$ Re at all local times) are populated principally through dynamical processes with characteristics distinct from those of quasi-stationary convection.

(31) Frequency gap formation in electromagnetic cyclotron wave distributions, by B. H. Mauk, Geophys. Res. Lett., 10, 635, 1983.

This letter addressed in detail the structure of the gap near the helium cyclotron frequency observed within the statistical distribution of the frequencies of electromagnetic cyclotron waves encountered at synchronous altitudes. It is shown that, at most, two-thirds of the gap (the high frequency portion) results from linear dispersion effects. It is suggested that at least one-third of the gap (the low frequency portion) results from nonlinear, off-resonant absorption of the waves by means of near cyclotron resonance with singly charged helium ions.

(32) Average electron precipitation patterns and visual aurora characteristics during geomagnetic quiescence, by K. Makita and C. I. Meng, J. Geophys. Res., (in press), 1983.

The pattern of polar-region electron precipitations during geomagnetically quiet periods (i.e., mostly under the positive IMF B_z condition) is examined on the basis of the electron precipitation data from the Defense Meteorological Satellite Program F2, F3, and F4 satellites. The auroral electron precipitation during quiet times consists of two distinctly different types as it does in active times. The high latitude part of the precipitation region has an average electron energy lower than 500 eV with bursty structure, and the average energy of the low latitude part is generally

higher than 500 eV with smoother spatial structure. It is found that during quiet times the average location of the poleward boundary the electron precipitation is particularly high at a geomagnetic latitude of about 82° to 84° in the morning, noon and evening sectors and at about 81° to 82° in the midnight sector, while the equatorward edge is at about 70° in the morning, noon and evening sectors and at about 69° in the midnight sector. The latitudinal width of the region of auroral electron precipitation is unusually large, indicating a widening of the auroral oval in geomagnetic quiescence. DMSP auroral image data further reveal that there is no bright discrete optical aurora in the region of low-average-energy electron precipitation while faint stable auroral arcs sometimes are seen in the equatorial region of the high-average energy electron precipitation.

The location of the poleward boundary is affected by the magnitude of the northward interplanetary magnetic field (IMF) component; however, the location of the precipitation equatorward boundary and of the transition boundary are not related to the positive IMF B_z magnitude. These results indicate that the unusually high latitude of the precipitation poleward boundary is the consequence of a very small number of geomagnetic flux lines interconnected with the IMF during a northward IMF condition and also that the size of the polar cap is inversely controlled by the magnitude of the northward B_z component. The insensitivity of the transition and equatorward precipitation boundaries to the northward IMF B_z

can be used to infer that their dynamics are dominated by the magnetospheric internal processes and not by the direct consequence of the solar-magnetospheric interaction.

(33) The relation of the cusp precipitating electron flux to the solar wind and interplanetary magnetic field, by M. Candidi and C. I. Meng, J. Geophys. Res., (submitted), 1983.

The temporal variation of the precipitating electron flux in the energy range 47 eV to 1 keV detected in the low altitude cusp is studied as a function of the solar wind parameters and the interplanetary magnetic field (IMF) B_z component. It is found that the cusp electron flux intensity in the polar cusp region depends nonlinearly on the solar wind plasma density and also that it is higher in the negative IMF B_z period than in the positive IMF B_z period. Both these facts are consistent with the predictions of the existing models of magnetic field line merging at the magnetopause; however, the possibility that nonlinear diffusion processes predominate cannot be eliminated.

(34) Temporal and spatial variations of the polar cap dimension and its relation to the energy input rate ε and AE index, by K. Makita, C.-I. Meng and S.-I. Akasofu, J. Geophys. Res., (submitted), 1983.

We present a new method to monitor the total open magnetic flux in the magnetosphere on the basis of time variations of the dimension of the polar cap determined from

the electron precipitation data: the DMSP satellite data, both along the dawn-dusk and noon-midnight meridians, a:e used. Assuming that the polar cap boundary can approximately be identified as the boundary of the intense precipitation region of the low energy electrons, it is found that both the dawn-dusk and noon-midnight dimensions of the polar cap tend to vary in harmony with the AE index. On the basis of the simultaneous ISEE-3 data, it is found that the increase begins about 30-60 minutes after the southward turning of the IMF (and an increase of the ε parameter), but prior to the corresponding increase of the AE index. The period of the maximum dimension of the polar cap approximately coincides with the period of the maximum AE value. The decrease begins at about the same time as the substorm activity begins to subside, but it continues well after the AE index reduces very small values.

The size of the polar cap may be considered as a measure of the open magnetic flux and thus of magnetic energy in the magnetotail. Thus, our results suggest that the magnetic energy in the magnetotail increases and decreases in harmony with the growth and decay of substorm activity, respectively.

VIII. CONCLUDING REMARK

As evidenced by our recent results and publications as summarized here we have pursued a vigorous program involved in the study of various aspects of the polar region particle precipitations, auroral phenomena and related magnetosphere dynamics. These aspects extend from improving our understanding of the phenomenological relationships between magnetospheric parameters to improving our understanding of basic mechanisms which ultimately are responsible for the phenomenological relationships. We will continue making advancements in the areas discussed herein. Finally, we would like to express our gratitude to Air Force Office of Scientific Research, Director of Physical and Geophysical Sciences, and Dr. Henry Radoski for their continuous interests, guidance and support to the space physics programs performed at The Johns Hopkins University, Applied Physics Laboratory.

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